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VOLUME, YIELD, AND GROWTH OF LOBLOLLY PINE IN THE MID-ATLANTIC COASTAL REGION

PROGRESS REPORT ON PULPWOOD STANDS

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FOREWORD

This technical note is a progress report on one of the Station's current studies of growth, yield, and measurement of forest trees. It is restricted to loblolly pine, to pulp-timber sizes, and to the mid-Atlantic coastal region. The final report on growth and yield of loblolly pine, to be issued in printed form within a few years, will contain information not only for pulp-timber sizes but for saw-timber sizes and for other products obtainable from loblolly pine. Numerous requests on the Station for information on growth and yield of loblolly pine are responsible for issuance of this preliminary information.

It will be obvious that this technical note is not intended for distribution to the general public, or to others unskilled in forest measurement. It was prepared as a reference for technical foresters in the U. S. Forest Service, Soil Conservation Service, other Federal services, State Foresters and other cooperating agencies.

The authors have tried to give as complete a picture as possible of the fundamental growth, yield, and volume relationships thus far found to be significant. It is believed that the technical audience to which this report is addressed will prefer this approach to any simplification requiring omission or absorption of certain fundamental relationships. It is left to the practicing forester to use the relationships which by trial he finds most applicable for specific jobs.

Constructive criticism will be helpful in preparing the final printed report and will be welcomed.

R. E. McArdle,
Director.

CONTENTS

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VOLUME, GROWTH, AND YIELD OF LOBLOLLY PINE IN THE MID-ATLANTIC COASTAL REGION

Progress Report on Pulpwood Stands

INTRODUCTION

The recent and continued expansion of the pulp and paper industry in the South has created an urgent demand for information on the growth and production of southern pine pulpwood. It is the purpose of this report to summarize the mensurational phases of volume, growth, and yield of loblolly pine pulpwood in the mid-Atlantic coastal region.

Although this progress report deals exclusively with pulpwood it is generally believed that the growing of pulpwood alone is economically unsound in the long run. There are few stands that cannot be made to yield, in addition to pulpwood, a variety of products such as high-grade sawlogs, poles, and piling, which will return a higher income to the landowner than will the exclusive production of pulpwood. Heavy yields of pulpwood can be obtained from the less promising trees, from low-grade sawlogs, the tops of saw-timber trees, and from thinnings. Cuttings designed to harvest trees and parts of trees which have low prospective value for other products can supply a large proportion of the pulpwood demand. Nevertheless, many forest stands are now or will be managed primarily for the production of pulpwood; for these stands the following mensurational information is presented.

The portion of the mid-Atlantic coastal region in which loblolly pine occurs in commercial stands is a belt varying from 50 to 150 miles wide extending from Wilmington, Delaware, to the Savannah River and including parts of Delaware, Maryland, Virginia, North Carolina, and South Carolina. One side is bounded by the Atlantic Ocean and the other is nearly a straight line extending from Wilmington to a point about 30 miles west of Augusta, Georgia, (figure 1). The total area of this belt is approximately 45 million acres, of which about 26 percent is agricultural land, 66 percent forest land, and 8 percent includes urban centers, railroads, highways, salt marsh, and unproductive sand banks.

Figure 1.--Area in the mid-Atlantic region in which loblolly pine is commercially important for pulpwood. Each dot represents the location of a stand in which the yield of loblolly pine was measured.

MEASUREMENT OF THE PULPWOOD CROP

Volumes of Standing Trees

It is frequently necessary to estimate the amount of pulpwood available in certain trees or stands. To do this, tables for average volumes of trees of given diameters and heights are used. Knowing the height and diameter of a given tree, the estimated volume of pulpwood can thus be read directly from the appropriate volume table. Table 1, giving total cubic volume, less bark, including stump and top, is the base table computed by the logarithmic method suggested by Schumacher and Hall[1]; tables 2, 3, 4, 5, and 6, for merchantable volume, were converted from this table[2].

It is sometimes desirable to know how many pulpwood bolts can be cut from trees of different sizes. Table 7 gives the average number of 5-foot bolts which can be cut between a 0.7-foot stump and a 4.0-inch top, outside bark.

1/ Schumacher, F. X., and Hall, F. dos S. 1933. Logarithmic expression of timber-tree volume. Jour. Agr. Research 47: 719-734.

2/ None of these tables recognize any allowance for cull, crook, or trimming. The tables expressed in cords or units are on the basis of freshly piled wood. Because of the various units of pulpwood measure commonly used at present, it is planned to give 4 bases of measurement in these tables and, so far as practicable, in all tables and figures of stacked volume. These bases, all employing the use of straight, round bolts with branch stubs and knots trimmed flush, are as follows:

Rough cords - unpeeled 5-foot bolts in piles 8 feet long and 3.2 feet high, occupying 128 cubic feet of space.

Peeled cords - peeled 5-foot bolts in piles 8 feet long and 3.2 feet high, occupying 128 cubic feet of space.

Rough units - unpeeled 5-foot bolts in piles 8 feet long and 4 feet high, occupying 160 cubic feet of space.

Peeled units - peeled 5-foot bolts in piles 8 feet long and 4 feet high, occupying 160 cubic feet of space.

The volume tables are directly applicable in the majority of second-growth loblolly pine stands in the mid-Atlantic region. It should be noted, however, that trees over 60 years of age will generally have less taper and, accordingly, more volume than the trees upon which these tables are based. Within these limitations, and except in cases where minor changes are necessary for specific local application, these tables are considered applicable to most loblolly pine stands.

Table 1.—*Total cubic-foot volume table: second-growth loblolly pine*[1]

Diameter breast high (inches)		Volume in cubic feet (entire stem, less bark) for a total height of —										Basis: trees (number)
Outside bark	Inside bark	10 feet	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	
2	1.6	0.073	0.157	0.244	0.335	0.428	....	....	....	....	....	......
3	2.5	.162	.346	.540	.740	.946	1.16	....	....	....	....	9
4	3.3	.284	.608	.949	1.30	1.66	2.03	2.40	....	....	....	14
5	4.1	.440	.941	1.47	2.01	2.57	3.14	3.72	4.30	....	....	42
6	4.9	.628	1.34	2.10	2.87	3.67	4.48	5.31	6.15	....	....	26
7	5.8	....	1.82	2.83	3.88	4.96	6.06	7.18	8.31	9.46	....	42
8	6.6	....	2.36	3.68	5.04	6.44	7.87	9.32	10.79	12.28	....	52
9	7.4	....	2.97	4.63	6.35	8.11	9.91	11.74	13.59	15.46	....	76
10	8.3	....	....	5.69	7.81	9.97	12.18	14.42	16.70	19.00	....	59
11	9.2	....	....	6.86	9.40	12.01	14.67	17.38	20.12	22.90	25.70	41
12	10.0	....	....	8.13	11.15	14.24	17.40	20.60	23.85	27.14	30.47	31
13	10.9	....	....	9.51	13.04	16.65	20.34	24.09	27.89	31.74	35.63	33
14	11.8	....	....	11.00	15.07	19.25	23.51	27.85	32.24	36.69	41.19	21
15	12.6	....	....	.....	17.25	22.03	26.92	31.87	36.90	41.99	47.14	18
16	13.7	....	....	.....	19.57	25.00	30.53	36.16	41.86	47.64	53.48	12
17	14.6	....	....	.....	22.03	28.15	34.37	40.71	47.14	53.64	60.21	2
18	15.5	....	....	.....	.....	31.47	38.45	45.53	52.71	59.98	67.33	2
19	16.5	....	....	.....	.....	34.98	42.73	50.60	58.59	66.67	74.84	......
20	17.5	....	....	.....	.....	38.68	47.24	55.94	64.77	73.70	82.74	......
												480

[1] Trees selected from 32 stands in the coastal plain of North Carolina and South Carolina. Volume includes peeled stump, stem, and top. Stump 0.7 feet high. Volumes computed by Smalian's formula. Tabular values computed from regression equation: Logarithm (total volume inside bark) = 1.9557 Logarithm (diameter breast high, outside bark) + 1.0971 Logarithm (total height) - 2.8209. Standard error of estimate = ± 10.02 percent. Average deviation = ± 7.41 percent.

Table 2.—*Merchantable cubic-foot volume table: second-growth loblolly pine* 1/

Diameter breast high outside bark (inches)	Volume, less bark, in cubic feet (to a 4.0-inch top outside bark), for a total height of:									Basis: trees (number)
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	
5..........	0.46	0.80	1.28	1.77	2.36	3.01	3.59	.....	.....	42
6..........	.74	1.32	2.08	2.96	3.76	4.55	5.37	.....	.....	26
7..........	1.07	2.06	3.17	4.22	5.29	6.37	7.48	8.63	.....	42
8..........	1.57	2.96	4.30	5.66	7.06	8.48	9.94	11.40	.....	52
9..........	2.20	3.91	5.56	7.30	9.07	10.86	12.71	14.53	.....	76
10..........	....	4.92	6.99	9.12	11.29	13.51	15.73	17.96	.....	59
11..........	....	6.07	8.56	11.13	13.76	16.42	19.07	21.80	24.54	41
12..........	....	7.32	10.41	13.33	16.42	19.55	22.70	25.94	29.25	31
13..........	....	8.66	12.15	15.71	19.28	22.98	26.70	30.47	34.20	33
14..........	....	10.12	14.16	18.21	22.39	26.65	30.95	35.23	39.55	21
15..........	....	.....	16.28	20.93	25.74	30.60	35.42	40.86	45.87	18
16..........	....	.....	18.51	23.88	29.32	34.71	40.72	46.36	52.96	12
17..........	....	.....	20.93	26.97	33.00	39.18	45.87	53.10	59.62	2
18..........	....	.....	.....	30.21	36.90	44.30	52.18	59.38	66.66	2
19..........	....	.....	.....	33.58	41.56	49.43	58.01	65.99	74.09	....
20..........	....	.....	.....	37.13	45.96	55.39	64.13	72.97	81.91	....
										457

1/ Trees selected from 32 stands in the coastal plain of North Carolina and South Carolina. Volume includes peeled stem above a 0.7-foot stump to a top diameter outside bark of 4.0 inches.

Table 3.—Merchantable volume in cords of peeled wood: second-growth loblolly pine[1/]

Diameter breast high outside bark (inches)	Volume in peeled cords (to a 4.0-inch top, outside bark), for a total height of:								
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet
5	0.005	0.009	0.014	0.019	0.026	0.033	0.039	.....	.....
6	.008	.014	.022	.032	.040	.048	.057	.....	.....
7	.011	.022	.033	.044	.056	.067	.079	0.091	.....
8	.016	.031	.044	.058	.073	.088	.103	.118	.....
9	.022	.040	.057	.075	.092	.111	.130	.148	.....
10	.....	.050	.070	.092	.114	.137	.159	.181	.....
11	.....	.061	.085	.111	.138	.164	.191	.218	0.246
12	.....	.072	.103	.132	.163	.194	.226	.258	.291
13	.....	.085	.120	.155	.190	.227	.264	.301	.338
14	.....	.099	.139	.178	.220	.262	.304	.346	.389
15	.....	.....	.159	.204	.252	.299	.346	.398	.448
16	.....	.....	.180	.232	.286	.339	.397	.450	.515
17	.....	.....	.204	.262	.320	.380	.446	.515	.581
18	.....	.....	.....	.294	.360	.431	.508	.578	.649
19	.....	.....	.....	.327	.405	.478	.565	.641	.719
20	.....	.....	.....	.361	.448	.538	.625	.709	.794

[1/] Volume includes peeled stem above a 0.7-foot stump to a top diameter, outside bark, of 4.0 inches. Conversion based on cords (128 cu. ft.) of freshly stacked peeled wood, cut in bolts 5 feet long. To compute number of trees required to make a cord of peeled wood, divide 1.0 by tabular values. Basis: same as table 2.

Table 4.—*Merchantable volume in units of peeled wood: second-growth loblolly pine*[1/]

Diameter breast high outside bark (inches)	Volume in peeled units (to a 4.0-inch top, outside bark), for a total height of:								
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet
5	0.004	0.007	0.011	0.015	0.021	0.026	0.031	.....	.....
6	.006	.011	.018	.026	.032	.038	.046	.....	.....
7	.009	.018	.026	.035	.045	.054	.063	0.073	.....
8	.013	.025	.035	.046	.058	.070	.082	.094	.....
9	.018	.032	.046	.060	.074	.089	.104	.118	.....
10	.....	.040	.056	.074	.091	.110	.127	.145	.....
11	.....	.049	.068	.089	.110	.131	.153	.174	0.197
12	.....	.058	.082	.106	.130	.155	.181	.206	.233
13	.....	.068	.096	.124	.152	.182	.211	.241	.270
14	.....	.079	.111	.142	.176	.210	.243	.277	.311
15	.....	.....	.127	.163	.202	.239	.277	.318	.358
16	.....	.....	.144	.186	.229	.271	.318	.360	.412
17	.....	.....	.163	.210	.256	.304	.357	.412	.465
18	.....	.....	.....	.235	.288	.345	.406	.462	.519
19	.....	.....	.....	.262	.324	.382	.452	.513	.575
20	.....	.....	.....	.289	.358	.430	.500	.567	.635

1/ Volume includes peeled stem above a 0.7-foot stump to a top diameter, outside bark, of 4.0 inches. Conversion based on units (160 cu. ft.) of freshly stacked peeled wood, cut in bolts 5 feet long. To compute number of trees required to make a unit of peeled wood, divide 1.0 by tabular values. Basis: same as table 2.

REVISION OF TABLE 5

20	.488	.590	.695	.790	.886	.980

Includes unpeeled stem above 0.7-foot stump to a top diameter o.b. of 4.0 inches.

Conversion based on 128-foot cord freshly stacked unpeeled wood cut in 5.0-foot bolts. To compute number of trees required for one cord of rough wood, divide 1.0 by tabular values.

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as table 2.

REVISION OF TABLE 5 - TECHNICAL NOTE 33 - MERCHANTABLE VOLUME IN CORDS OF ROUGH WOOD - SECOND-GROWTH LOBLOLLY PINE

D.b.h. outside bark (inches)	Volume in rough cords to a 4-inch top o.b. by total height in feet								
	20	30	40	50	60	70	80	90	100
5	0.008	0.013	0.019	0.026	0.033	0.041	0.048		
6	.012	.020	.031	.043	.053	.063	.073		
7	.017	.031	.046	.060	.074	.087	.100	0.114	
8	.024	.044	.062	.079	.097	.114	.131	.148	
9	.034	.057	.079	.101	.123	.144	.165	.186	
10		.071	.098	.125	.151	.177	.202	.228	
11		.088	.119	.151	.182	.213	.243	.274	0.304
12		.105	.144	.179	.216	.252	.287	.324	.360
13		.124	.168	.210	.252	.294	.336	.378	.418
14		.144	.195	.243	.292	.340	.388	.435	.482
15			.223	.278	.334	.389	.442	.502	.556
16			.253	.316	.380	.439	.506	.568	.639
17			.285	.356	.426	.495	.569	.648	.718
18				.398	.476	.558	.645	.723	.801
19				.442	.534	.621	.716	.802	.888
20				.488	.590	.695	.790	.886	.980

Includes unpeeled stem above 0.7-foot stump to a top diameter o.b. of 4.0 inches.

Conversion based on 128-foot cord freshly stacked unpeeled wood cut in 5.0-foot bolts. To compute number of trees required for one cord of rough wood, divide 1.0 by tabular values.

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Table 5.—*Merchantable volume in cords of rough wood: second-growth loblolly pine*[1]

Diameter breast high outside bark (inches)	Volume in rough cords (to a 4.0-inch top, outside bark), for a total height of:								
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet
5	0.006	0.011	0.017	0.024	0.031	0.040	0.048	.....	.....
6	.010	.017	.027	.038	.048	.059	.069	.....	.....
7	.014	.026	.040	.053	.066	.080	.093	0.107	.....
8	.019	.037	.054	.070	.088	.106	.123	.142	.....
9	.027	.048	.068	.089	.111	.133	.155	.178	.....
10	.....	.060	.084	.110	.137	.163	.190	.217	.....
11	.....	.072	.102	.133	.164	.196	.228	.260	0.293
12	.....	.....	.123	.158	.194	.231	.269	.307	.346
13	.....	.....	.142	.184	.226	.269	.312	.357	.400
14	.....	.....	.165	.212	.260	.310	.360	.410	.461
15	.....	.....	.188	.242	.298	.353	.410	.467	.529
16	.....	.....	.213	.275	.337	.398	.467	.532	.610
17	.....	.....	.....	.309	.377	.446	.526	.610	.685
18	.....	.....	.....	.345	.422	.505	.595	.676	.763
19	.....	.....	.....	.383	.474	.562	.662	.752	.847
20	.....	.....	.....	.424	.524	.633	.735	.833	.934

1/ Volume includes unpeeled stem above a 0.7-foot stump to a top diameter, outside bark, of 4.0 inches. Conversion based on cords (128 cu. ft.) of freshly stacked unpeeled wood, cut in bolts 5 feet long. To compute number of trees required to make a cord of rough wood, divide 1.0 by tabular values. Basis: same as table 2.

REVISION OF TABLE (

Includes unpeeled stem above 0.7-foot stump to a top diameter of 4.0 inches.

Conversion based on 160-foot unit freshly stacked unpeeled wood cut in 5.0-foot bolts. To compute number of trees required for one unit of rough wood, divide 1.0 by tabular values.

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REVISION OF TABLE 6 - TECHNICAL NOTE 33 - MERCHANTABLE VOLUME IN UNITS OF ROUGH WOOD - SECOND-GROWTH LOBLOLLY PINE

D.b.h. outside bark (inches)	Volume in rough units to a 4-inch top o.b. by total height in feet: 20	30	40	50	60	70	80	90	100
5	0.006	0.010	0.015	0.021	0.027	0.033	0.039		
6	.010	.016	.025	.034	.042	.050	.058		
7	.014	.025	.037	.048	.059	.069	.080	0.091	
8	.020	.035	.049	.063	.077	.091	.105	.118	
9	.027	.046	.063	.081	.098	.115	.132	.149	
10		.057	.079	.100	.121	.141	.162	.182	
11		.070	.096	.121	.146	.170	.194	.219	0.243
12		.084	.115	.144	.173	.201	.230	.259	.288
13		.099	.134	.168	.202	.235	.269	.302	.335
14		.115	.156	.194	.234	.272	.310	.348	.385
15			.178	.222	.267	.311	.353	.402	.445
16			.202	.253	.304	.352	.405	.454	.512
17			.228	.285	.341	.396	.455	.519	.574
18				.319	.380	.446	.516	.579	.641
19				.354	.428	.497	.573	.642	.711
20				.390	.472	.556	.632	.709	.784

Includes unpeeled stem above 0.7-foot stump to a top diameter of 4.0 inches.

Conversion based on 160-foot unit freshly stacked unpeeled wood cut in 5.0-foot bolts. To compute number of trees required for one unit of rough wood, divide 1.0 by tabular values.

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Table 6.—Merchantable volume in units of rough wood: second-growth loblolly pine[1]

Diameter breast high outside bark (inches)	Volume in rough units (to a 4.0-inch top, outside bark), for a total height of:								
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet
5	0.005	0.009	0.014	0.019	0.025	0.032	0.038	.....	.....
6	.008	.014	.022	.030	.038	.047	.055	.....	.....
7	.011	.021	.032	.042	.053	.064	.074	0.086	.....
8	.015	.030	.043	.056	.070	.085	.098	.144	.....
9	.022	.038	.054	.071	.089	.106	.124	.142	.....
10	.....	.048	.067	.088	.110	.130	.152	.174	.....
11	.....	.058	.082	.106	.131	.157	.182	.208	0.234
12	.....	.....	.098	.126	.155	.185	.215	.246	.277
13	.....	.....	.114	.147	.181	.215	.250	.286	.320
14	.....	.....	.132	.170	.208	.248	.288	.328	.369
15	.....	.....	.150	.194	.238	.282	.328	.374	.423
16	.....	.....	.170	.220	.270	.318	.374	.426	.488
17	.....	.....	.....	.247	.302	.357	.421	.488	.548
18	.....	.....	.....	.276	.338	.404	.476	.541	.610
19	.....	.....	.....	.306	.379	.450	.530	.602	.673
20	.....	.....	.....	.339	.419	.506	.588	.666	.747

[1] Volume includes unpeeled stem above a 0.7-foot stump to a top diameter, outside bark, of 4.0 inches. Conversion based on units (160 cu. ft.) of freshly stacked unpeeled wood, cut in bolts 5 feet long. To compute number of trees required to make a unit of rough wood, divide 1.0 by tabular values. Basis: same as table 2.

Table 7.--*Average number of 5-foot pulpwood bolts which can be cut from loblolly pine trees above a stump of 0.7 feet to a merchantable top of 4.0 inches, outside bark*[1]

Diameter breast high outside bark (Inches)	Number of 5-foot bolts per tree, for a total height of:								
	20 feet	30 feet	40 feet	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet
5	1.5	2.1	2.9	3.5	4.2	4.9	5.8	....	....
6	2.0	2.9	3.9	4.6	5.6	6.6	7.5	....	....
7	2.2	3.4	4.5	5.6	6.9	8.5	9.4	10.3	....
8	2.3	3.8	5.0	6.4	7.7	9.6	10.7	11.6	....
9	2.3	4.1	5.3	6.9	8.3	10.4	11.6	12.3	....
10	....	4.3	5.5	7.2	8.8	10.9	12.3	12.8	....
11	....	4.4	5.7	7.4	9.2	11.3	12.6	13.2	14.4
12	....	4.5	5.9	7.6	9.5	11.6	12.9	13.5	14.7
13	....	4.5	6.0	7.6	9.7	11.8	13.1	13.8	15.0
14	....	4.5	6.1	7.7	9.8	11.9	13.3	14.0	15.3
15	....	....	6.2	7.7	9.9	12.0	13.4	14.2	15.5
16	....	....	6.2	7.8	9.9	12.0	13.5	14.4	15.6
17	....	....	6.3	7.8	10.0	12.1	13.6	14.5	15.6
18	....	....	....	7.8	10.0	12.1	13.7	14.6	15.7
19	....	....	....	7.9	10.0	12.2	13.8	14.6	15.7
20	....	....	....	7.9	10.1	12.2	13.8	14.7	15.7

[1] Basis: same as table 2.

Contents of Stacked Cords

Volumes in the preceding tables are given in terms of cords and units for trees of different sizes, representing measures of stacked volume and giving only approximate indications of the amount of usable wood in the trees. In the present study[3/] it was found that a cord or unit of freshly piled, unpeeled, straight, round loblolly pine pulpwood contained an average of 64 percent solid wood, 19 percent bark, and 17 percent air space. Peeled cords and units averaged 77 percent solid wood and 23 percent air space. There is, however, considerable variation in the amount of usable wood in stacked piles, depending upon: the size of the pile, the length, diameter, and form of the bolts, the presence of bark, the presence of branch stubs or knots, whether the wood is round or split, the care in stacking, and the length of time piled. Since most pulp companies prefer reasonably straight wood and require that knots be trimmed flush, the most important factors influencing the amount of usable wood in a pile of given dimensions are: the diameter of the bolts and the presence of bark. Figure 2 indicates that the percentage of wood volume in cords or units for peeled and rough wood varies considerably with the average diameter of the bolts in the pile[4/].

3/ In which 246 loblolly pine trees were cut into 5-foot bolts and stacked in units.

4/ Theoretically and geometrically, cords of perfectly cylindrical bolts of wood will have the same solid cubic volumes regardless of the diameter of the wood, provided that the sticks within a given pile are uniform. Practically, however, wood is never perfectly cylindrical or regular and solid volumes per cord do differ. For wood of given length, these differences must be attributed to characteristics which are associated with diameter. Factors contributing to the reduction of solid volume per cord, such as sweep, crook, knots, and taper, are commonly associated with bolts of small diameters.

It is apparent from figure 2 (A) that the use of an average converting factor of 77 percent for peeled cords or units made up of bolts averaging less than 7 inches in diameter results in an overestimate of the amount of solid wood. In cords or units composed of bolts larger than 7 inches, more than 77 percent of the stacked space is occupied by solid wood. Similarly, rough cords or units, as shown in figure 2 (B), contain less than 64 percent wood volume when made up of bolts smaller than 7.5 inches and more than 64 percent wood volume when made up of bolts greater than 7.5 inches in diameter.

For accurate conversion of stacked volume into usable volume and for equitable buying and selling of pulpwood it is therefore necessary to consider the relationship between the size of the bolts and the solid volume of the stacked pile. However, it is impractical to measure the bolts in a pile in order to determine the correct converting factor. Inasmuch as the number of bolts in a fully stacked cord or unit is an index of the size of the bolts; that is, fewer bolts of large diameters are required to make a cord, it may be easier to associate the converting factors with number of bolts. Figure 3 shows the number of bolts required to make fully stacked cords and units of rough and peeled wood for different average bolt diameters[5]. Combining figures 2 and 3, converting factors can be obtained when the number of bolts per cord or unit is known. This can be further simplified by associating the converting factors with the number of bolts per square foot of side-face area, as in figure 4.

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[5] It will be noted in figure 3 that for a given average diameter, several more bolts are required to make a cord of rough wood than one of peeled wood. This is because of the resiliency of the bark, permitting more compact piling.

It is therefore unnecessary to have fully stacked cords or units, for the average number of bolts per square foot of side-face area can easily be determined by dividing the number of bolts in the pile by the product of length and height (in feet) of the stack.

Most pulp companies in the mid-Atlantic region require that bolts larger than 10 or 12 inches in diameter be split in half--if larger than 14 inches the bolts are to be quartered. The splitting of bolts tends to decrease the solid contents of cords by increasing the irregularities of the surface of the sticks. However, since only the large bolts are split it is quite possible that cords of such wood may contain more solid volume than round bolts of small diameters. Because of the varying proportions of split wood in a cord and the differences in the size of the pieces, it is doubtful that the converting factors herewith presented would apply to cords containing an appreciable amount of split wood. For such cords it is likely that the use of the average converting factors of 64 percent for rough wood and 77 percent for peeled wood will yield satisfactory results.

The converting factors presented apply to freshly piled wood. If the piles have been allowed to stand for a month or longer, or have been subjected to settling influences such as truck hauling or rail transportation, considerable vertical shrinkage will have taken place.

Following is an example of the application of converting factors: the mean length of each pulpwood stack is determined by averaging two measurements, made parallel to the ground, one taken at the top and the other at the bottom of the pile. The height of the stack is

measured perpendicular to the base of the pile at not more than 3-foot intervals, and the several measurements averaged to obtain the mean height. The product of the mean height and mean length, multiplied by the length of the pulpwood bolts, gives the cubic space occupied by the stacked wood. If many piles are to be measured or if the wood averages about 7 or 8 inches in diameter, the average converting factors of 64 percent for unpeeled wood and 77 percent for peeled wood will usually be satisfactory if the wood is freshly piled, round, and reasonably smooth. If a more accurate estimate is desired, the procedure is as follows:

Measurement of pile:

Length (top)	6.2 feet
Length (bottom)	6.8 feet
Length (mean)	6.5 feet
Height (1)	5.3 feet
Height (2)	4.4 feet
Height (3)	4.7 feet
Height (mean)	4.8 feet

Description of wood: Rough (unpeeled), freshly piled, round, straight, all knots trimmed flush, bolts 5 feet long, 140 bolts in pile.

Computations:

Stacked volume: 6.5 x 4.8 x 5.0 feet = 156.0 cubic feet.

Side-face area: 6.5 x 4.8 = 31.2 square feet. 140 bolts divided by 31.2 square feet = 4.49 bolts per square foot of side-face area.

Converting factor: From figure 4 (B);
for 4.49 bolts, 61.2 percent of the stacked space is occupied by solid wood.

Cubic volume of wood (excluding bark):
156.0 cubic feet x 61.2 percent = 95.5 cubic feet.

The practical implications of the relationship between the solid volume of a cord or unit and the diameters of the bolts comprising it may be illustrated by the following example:

From figure 2 (B) it is evident that there are 105 cubic feet of solid wood in a unit of rough bolts averaging 9 inches in diameter. If a unit of pulpwood is worth $4.50, then a single cubic foot of wood is worth $4.50 divided by 105 cubic feet or $0.0428. A unit made up of bolts averaging 6 inches has 98.5 cubic feet of solid wood or 6.5 cubic feet less than a 9-inch unit. A unit of 9-inch wood, therefore, should be worth 6.5 x $0.0428 or $0.28 more than a unit of 6-inch wood.

As indicated in figure 2, the solid volume per cord or unit is correlated with the size of the bolts making up the pile. It is to be expected that bolts cut from trees of large diameter, the bolts being large, will make stacks having more solid volume than piles made of bolts cut from smaller trees. This relationship is shown in figure 5 which gives the percentage of solid wood per cord or unit when made up of trees of given diameters--all bolts in a pile being cut from trees in the same diameter class. The curves in figure 5 were used

in the conversion of the table of merchantable cubic volume (table 2) to volume in cords and units (tables 3, 4, 5, and 6).

In general a consideration of converting factors shows: (1) the approximate magnitude of the relationship between the stacked unit of measure and the actual quantity of raw material available for manufacture; (2) the variations in solid wood volume as influenced by trees and bolt size; (3) the fact that within rather narrow limits a unit of wood made of large bolts or trees is worth more than a unit made of smaller bolts or trees.

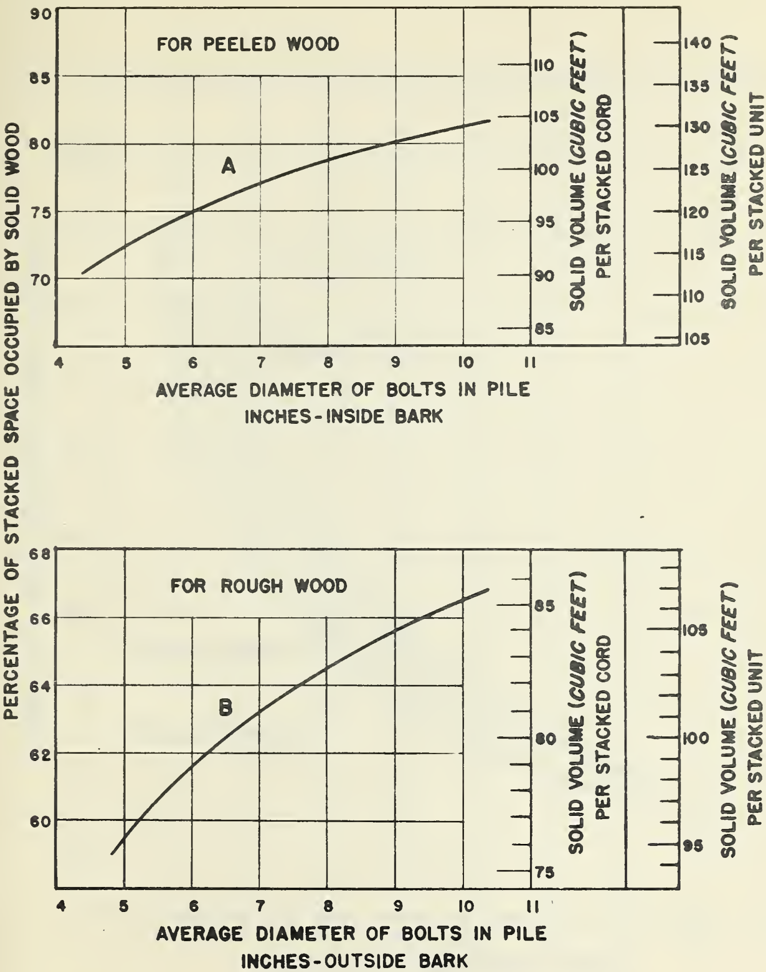

Figure 2.--Converting factors for loblolly pine pulpwood showing the percentage of stacked space occupied by solid wood (exclusive of bark) in piles having different average bolt diameters. (A) For peeled wood. (B) For rough (unpeeled) wood.

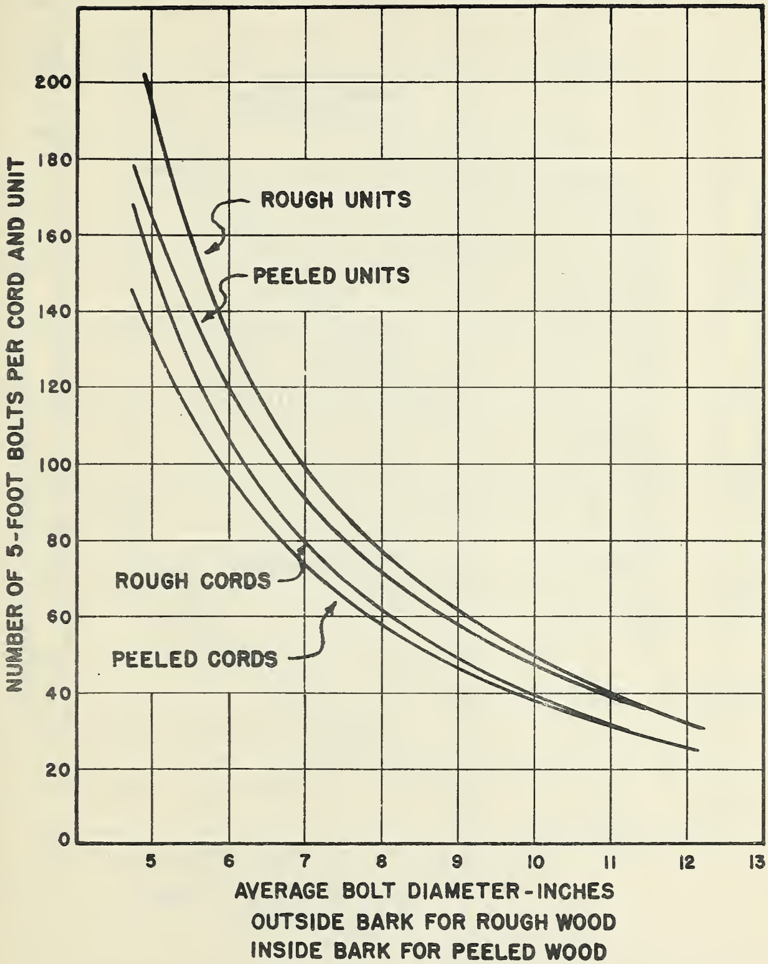

Figure 3.--Number of 5-foot bolts per cord (128 cubic feet) or unit (160 cubic feet); both rough and peeled wood by average diameter of bolts.

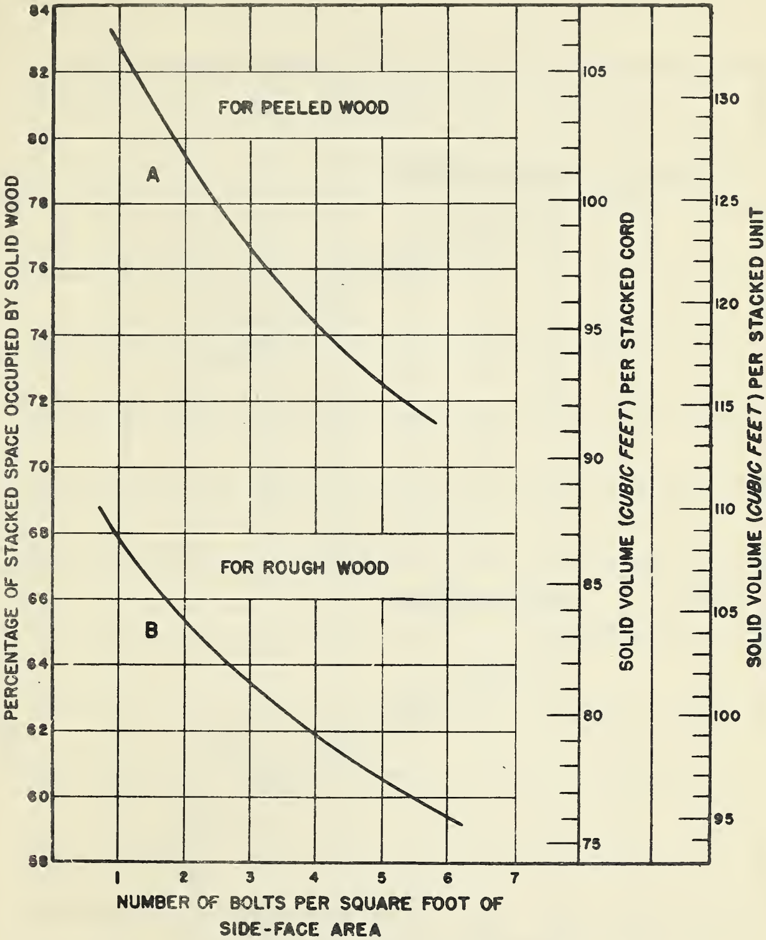

Figure 4.--Converting factors for loblolly pine pulpwood showing the percentage of stacked space occupied by solid wood (exclusive of bark) in piles containing different number of bolts per square foot of side-face area. (A) Per peeled wood. (B) For rough (unpeeled) wood.

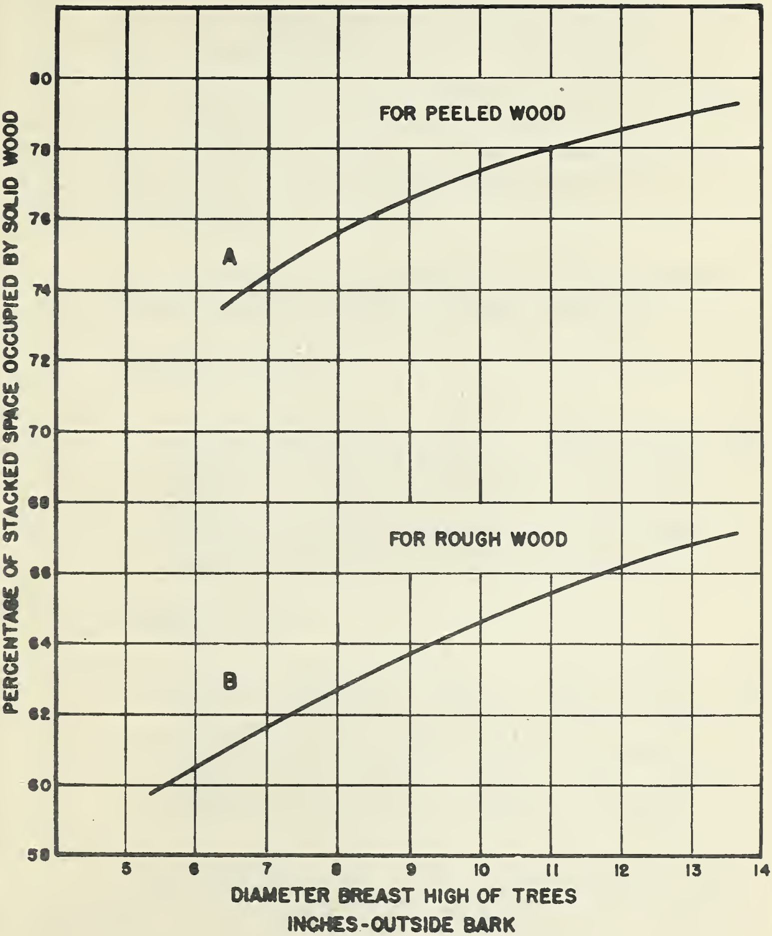

Figure 5.--Factors for use in converting cubic volumes in trees of different diameters into terms of stacked cords or units. (A) For peeled wood. (B) For rough wood.

Pens

Pulpwood newly cut or piled awaiting shipment is frequently stacked in pens, usually consisting of bolts arranged in alternate layers. Pens are generally 6 feet in height and each layer contains 2 bolts 5 feet long. As these are often used as a basis of payment for felling, bucking, peeling, and penning, or for purchase or sale of wood, it is desirable to have methods of estimating their solid or stacked contents.

Measurement of 47 pens on three operations gave the following average values:

Peeled wood:

Solid volume per pen: 31.5 cubic feet
Number of units per pen: 0.25 units
Number of pens per unit: 4.0 pens
Number of cords per pen: 0.31 cords
Number of pens per cord: 3.2 pens

Rough wood:

Solid volume per pen: 28.5 cubic feet
Number of units per pen: 0.23 units
Number of pens per unit: 4.3 pens
Number of cords per pen: 0.29 cords
Number of pens per cord: 3.4 pens

Individual pens show a wide range both in cubic-foot and stacked contents, due primarily to the size of the bolts making up the pens. Not only are fewer bolts of large diameters required to make up pens of constant height (6 feet), but such bolts also contribute more to the solid cubic content of the pens.

Hence fewer pens are required to make a unit or cord when bolts are large. As shown in figure 6, the number of pens required to make a unit of stacked wood ranges from 3 to 6, depending upon the number of bolts per pen, which reflects the influence of bolt diameter[6/].

If payment for woods work is made on the basis of $1.25 per unit and a flat converting factor of 5.0 pens per unit is used, then from figure 6 we see that only 0.83 units of rough wood is produced by $1.25 worth of labor when the wood is so small as to require 28 bolts per pen. If wood is of large enough diameter to average 18 bolts per pen, then $1.25 worth of labor produces about 1.20 units and for every 25 pens paid for, an "over-run" of 1.8 units is produced.

For rough wood averaging 22 or 24 bolts per pen or approximately 6 or 7 inches in diameter a converting factor of 5.0 pens per unit seems reasonably accurate. However, where wood averages smaller or larger than the above, fairness to all parties concerned requires consideration of the relationship shown in figure 6.

6/ The values given in figure 6 are for units of stacked wood (160 cubic feet). To convert into cords (128 cubic feet), multiply the number of units per pen by 1.25 and the number of pens per unit by 0.8. For pen heights other than 6 feet, take simple proportions; that is, a pen 5.2 feet high will contain 5.2/6.0 as much as a pen 6.0 feet high. All values are for freshly penned, straight, round, 5-foot bolts.

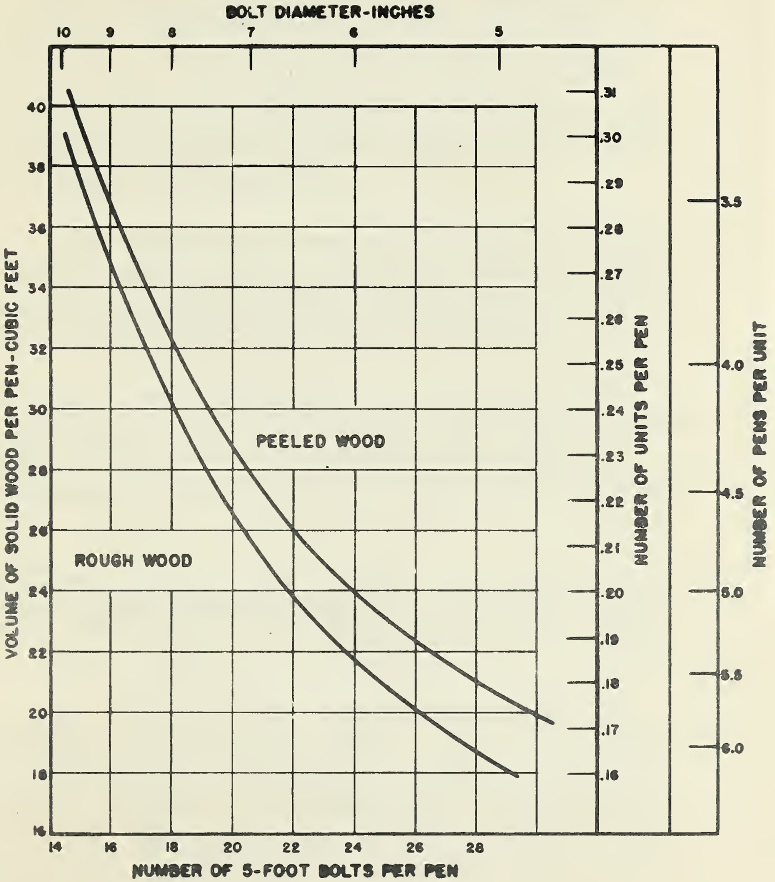

Figure 6.--Solid volume in cubic feet and stacked volume in units (160 cubic feet) of pens 6 feet high, two 5-foot bolts per layer.

GROWTH AND YIELD OF THE PULPWOOD CROP

Definitions

The tables presented of growth and yield are so-called "non-normal" tables, designed to predict growth and yield for even-aged, second-growth loblolly pine growing in pure or mixed stands of different densities of stocking. The following definitions explain some of the terms used in later discussions.

Yield - The loblolly pine wood content per acre measured in cubic feet, cords, or units. Since this progress report deals primarily with pulpwood, no board-foot tables are presented.

Basal area - The basal area of a tree is the area in square feet (including bark unless otherwise specified) of a cross section taken at breast height (4.5 feet above the average ground level).

Dominant and codominant trees - Trees with well-formed crowns that receive full sunlight from above and at least some sunlight from the sides.

Total age - The average age of dominant and codominant trees in the stand. This is usually determined either by taking increment borings at breast height or by making age counts on cut stumps. In the first case 3 years and in the second case 1 year must be added to the counted age.

Stocking - The degree to which an area is effectively covered with trees. In this report the index of stocking, termed "density index", is defined as the ratio (expressed as a percent

or decimal) of the observed number of trees per acre of all species to the number expected in fully stocked stands of loblolly pine.

Composition index - The ratio (expressed as a percent or decimal) of the basal area of pines to the basal area per acre of all trees.

Site index - The height attained by the average dominant and codominant trees at 50 years, in fully stocked stands, as a measure of site quality.

Even-aged stands - Stands in which the youngest and oldest loblolly pine trees are within 25 percent of the mean age of the dominant and codominant trees.

Lower diameter limit - The smallest-sized tree on each sample plot included in the compilation of the yield tables. This was defined as one-fifth the average diameter of the dominant and codominant pines and was used to exclude from the stand tally the multitude of small hardwoods frequently present under loblolly pine stands.

Mean annual increment - The average yearly increase per acre in the volume of a stand, computed by dividing its total volume by its age.

Periodic annual increment - The average yearly increase in volume per acre over a short period--here 5 years.

Factors Influencing Gross Yield

The gross yield of loblolly pine pulpwood in a second-growth forest at any given age is determined by the degree of stocking, the site quality, and the composition of the stand. The actual yields obtainable from any stand are affected by other factors also, such as the intensity of utilization and the amount of defect.

Stocking

The natural tendency of all forest stands is to approach and maintain a degree of stocking at which the site factors are most fully utilized on the production of wood. When this optimum condition is reached, stands are said to be "fully" or "normally" stocked. As yet, however, this definition of "normal stocking" is purely theoretical and practical means for its determination and measurement have not yet been developed. Various arbitrary indices are therefore used to indicate stocking. In this report the term "full stocking" means the average stocking of natural dense stands of loblolly pine. Full stocking is numerically defined by the relation between the number of trees per acre and their average diameter in the following equation:

Logarithm of number of trees per acre in fully stocked stands = -1.707 (logarithm of average diameter of trees in stand) + 4.1588.

Table 8 gives the number of trees per acre representing full stocking for stands of different average diameters. In determining the density index of any given stand, the actual number of trees present including all species, is expressed as a percent or decimal of the

number which a stand of the same average diameter would contain if it were fully stocked. The following example illustrates the procedure:

In a stand with an average diameter breast high, outside bark, (as determined from average basal area) of 6.4 inches, there are 500 trees per acre, whereas for a fully stocked stand with an average diameter of 6.4 inches there should be 607 trees (as read from table 8). The density index of the stand is therefore 500 divided by 607, 0.82 or 82 percent.

Site Quality

A complex of factors working together results in different degrees of productivity in various forest areas. These factors -- soil, drainage, rainfall, temperature, slope, aspect, and others -- go to make up site quality. It would be extremely difficult to evaluate the effect of these factors upon the potential productive capacity of an area. Probably the best index of this capacity is the volume of wood actually produced by a fully stocked stand on a given site. However, most forest stands are understocked and existing volume therefore is not usually indicative of the productive capacity of the site. For this reason it is desirable to use a more convenient index of site quality--the average height attained by dominant and codominant trees at a reference age of 50 years.

Figure 7 presents site index curves for fully stocked loblolly pine stands. The site index can easily be determined for a given stand, providing it is fully stocked, by the following procedure:

Determine the total age and height of 10 randomly selected dominant and codominant loblolly pine trees in the particular stand. Compute the average age and height of these trees. Refer these values to figure 7; the curve which most closely corresponds to these values indicates the site index of the stand.

When site index values are desired for areas supporting understocked or overstocked stands the average measured height must be corrected, since trees growing in such stands are usually shorter than they would be if grown in fully stocked stands. These corrections are given in table 9 for stands of different ages and densities of stocking. Thus, if the average height of the dominant and codominant trees in a 40-year old stand is 72 feet and the stand is 50 percent stocked, a correction of 6.0 feet (from table 9) is added. Referring to figure 7, a 40-year old stand with a corrected average height of 78 feet has a site index of 87 feet.

It is more difficult to obtain the site index of an area devoid of trees. Where such an area is adjacent to standing timber on land of apparently similar site quality, it may be assumed that the site index of the bare land is the same as the adjoining forested area. Where adjacent tracts of standing timber are not available, no method of determining site index is known.

Stand Composition

Loblolly pine in the mid-Atlantic Coastal region frequently occurs in mixture with other species. Since density of stocking is based on all trees of all species over a certain minimum size limit, the yield tables which follow must

take into account the proportion of other species in the stands if the yield of loblolly pine alone is to be determined. The composition index of a stand is defined as the ratio of the basal area of loblolly pine to the basal area of all trees over the minimum size limit in each stand. Other species of pine occuring in the stands, if less than 30 percent of the total number of pine stems, can be considered as loblolly pine in the composition index and yields. An example of the method of determining stand-composition index is as follows:

Total basal area of stand.....85.7 square feet
Basal area of loblolly pine...42.1 square feet
Basal area of other pines..... 3.4 square feet
Basal area of hardwoods.......40.2 square feet

$$\frac{\text{Basal area of pines}}{\text{Total basal area of stand}} = \frac{45.5}{85.7} = 0.531 \text{ or } 53.1 \text{ percent}$$

Table 8.--*Number of trees necessary for full stocking in loblolly pine stands of different average diameter breast high, outside bark*[1]

Diameter (inches)	Trees per acre	Diameter (inches)	Trees per acre	Diameter (inches)	Trees per acre	Diameter (inches)	Trees per acre
	Number		Number		Number		Number
5.0	924	9.0	339	13.0	181	17.0	115
5.2	864	9.2	326	13.2	176	17.2	113
5.4	812	9.4	314	13.4	172	17.4	110
5.6	762	9.6	303	13.6	168	17.6	108
5.8	718	9.8	293	13.8	164	17.8	106
6.0	677	10.0	283	14.0	160	18.0	104
6.2	641	10.2	274	14.2	156	18.2	102
6.4	607	10.4	265	14.4	152	18.4	100
6.6	575	10.6	256	14.6	148	18.6	98
6.8	547	10.8	248	14.8	145	18.8	96
7.0	520	11.0	240	15.0	142	19.0	94
7.2	496	11.2	233	15.2	139	19.2	93
7.4	473	11.4	226	15.4	136	19.4	91
7.6	452	11.6	220	15.6	133	19.6	90
7.8	433	11.8	214	15.8	130	19.8	89
8.0	414	12.0	207	16.0	127	20.0	87
8.2	397	12.2	201	16.2	124	20.2	86
8.4	381	12.4	196	16.4	121	20.4	84
8.6	366	12.6	191	16.6	119	20.6	83
8.8	352	12.8	186	16.8	117	20.8	82

1/ For the tree of average basal area.

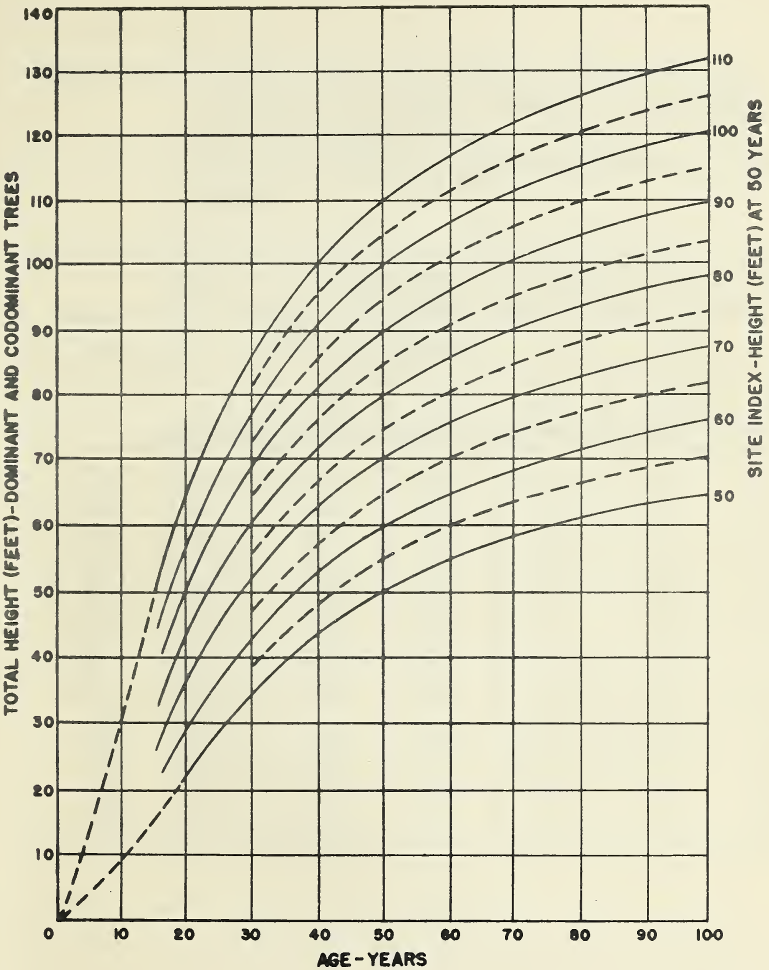

Figure 7.--Site index curves for loblolly pine growing in even-aged, fully-stocked stands. Basis: 149 plots.

Table 9.--*Corrections for effect of density of stocking on height growth of dominant and codominant trees, to obtain site index for understocked and overstocked stands*

Density index (percent)	Height corrections, in feet, to be added to average measured heights for stands of following ages:					
	10 years	20 years	30 years	40 years	50 years	60 years
20	4.0	6.5	7.5	8.0	8.5	9.0
30	3.5	6.0	7.0	7.5	8.0	8.0
40	3.0	5.5	6.0	6.5	7.0	7.0
50	2.5	4.5	5.0	6.0	6.0	6.0
60	2.0	3.5	4.0	4.5	4.5	4.5
70	1.0	1.5	2.0	2.5	2.5	2.5
80	0.5	1.0	1.0	1.5	1.5	1.5
90	0.5	0.5	0.5	0.5	0.5	0.5
100	0.0	0.0	0.0	0.0	0.0	0.0
110	0.5	0.5	0.5	0.5	0.5	0.5
120	1.0	1.5	2.0	2.5	3.0	3.0
130	2.5	4.0	4.5	5.0	5.5	6.0

Loblolly Pine Yields

It is seldom efficient to use yield tables to obtain an estimate of the inventory (or present volume per acre) where a fairly high degree of accuracy is desired. Forest managers will probably find that it is as economical to cruise a stand--either by sample plots or a 100 percent tally--as to measure the variables necessary for yield table use. For short term growth prediction, a well-planned system of growth projection from increment borings will produce as reliable an estimate as the growth tables. Nevertheless, yield and growth tables have a definite place in the management of forests. They demonstrate the behavior of stands throughout the rotation period; in fact, they contribute information as to the desirable length of the period. The tables show the amount of growth that can be attained under certain conditions, thereby indicating what can be accomplished by methods of management. For purposes of stand comparison, a rough estimate of the variables will give an approximation of the yield and growth. The utility of these tables, therefore, lies mainly in their value as guides or standards to which existing stands may be referenced.

The yield tables presented are so-called "non-normal" tables; that is, they give the volume of loblolly pine in stands of different densities and compositions growing on various qualities of site. As such, these tables overcome some of the weaknesses inherent in "normal" yield tables in that they are more generally applicable to existing stands. However, greater applicability is attained at increased expense, since it is necessary to determine not only the

age and site quality of a given stand but also its density and composition indices. Although the introduction of the latter two variables necessarily increases the complexity of the tables, it is evident that more precise estimates of yield can be obtained.

Cubic-foot yields include the wood contents of the entire peeled stem, including stump and top, but excluding bark and limbs, of all loblolly pine trees larger than one-fifth the average diameter of the dominant and codominant trees. The merchantable yields in cords and units allow for a minimum top diameter of 4.0 inches outside bark, a stump height of 0.7 feet, and no trimming allowance. Yield table volumes make no allowance for possible loss through defect, breakage, or incomplete woods utilization.

The yield in total cubic feet per acre for pure fully stocked stands of different ages and sites may be read from table 10[7]. The auxiliary table 11 presents reduction factors to be applied to table 10 to obtain cubic yields per acre for density and composition indices other than 100 percent. The following example illustrates the procedure for the use of tables 10 and 11:

For a given stand of 50 years of age, growing on site index 80, the density index is measured as 70 percent and the composition index as 80 percent. From table 10 the yield per acre for a stand of that age and site index is 4756

7/ The basic data for this and the following tables of growth and yield were obtained from 150 mechanically selected sample plots in the mid-Atlantic Coastal region. The values in table 10 and 11 were derived from the following regression equation:

Logarithm of yield per acre = − 13.7099 (reciprocal of stand age) + 0.9081 (logarithm of density index) + 0.0071 (composition index) + 0.0114 (site index) + 0.5123.

cubic feet. The reduction factor for density index 70 percent and composition index 80 percent is 0.5215 (read from table 11). Therefore, the yield in pine per acre for the given stand is 4756 x 0.5215 = 2480 cubic feet.

Table 12 gives the merchantable yield in units (160 cubic feet) of rough wood for trees 6.0 inches and larger, utilization being based on a 0.7-foot stump to a 4.0-inch top outside bark. The tabular values apply to stands of pure pine for different classes of density of stocking. To obtain yields per acre for stands having composition indices other than 100 percent or to obtain yields in terms of units of peeled wood or cords of rough or peeled wood, the reduction factors given in table 13 are multiplied by the values in table 12. For example:

For a 50-year-old stand, site index 80 feet, density index 60 percent, and composition index 70 percent, the merchantable yield per acre, read from table 12, is 26 units of rough wood. This yield, however, is for stands of 100 percent composition: for composition index of 70 percent the reduction factor given in table 13 is 0.642. Thus the yield for the illustrated stand is 26 units x 0.642 = 16.7 units of rough wood per acre. Applying additional reduction factors given in table 13 the yield per acre is 14 units of peeled wood (26 units x 0.538), or 20.8 cords of rough wood (26 units x 0.803), or 17.5 cords of peeled wood (26 units x 0.673).

Table 10.—*Loblolly pine yield per acre (total volume in cubic feet inside bark), all trees larger than one-fifth of average diameter of dominants included*

DENSITY INDEX = 100 PERCENT
COMPOSITION INDEX = 100 PERCENT[1]

Age (years)	Yield per acre, for site index---						
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet	Cubic feet
15......	495	644	837	1089	1416	1841	2394
20......	839	1091	1418	1845	2399	3119	4056
25......	1150	1496	1945	2529	3289	4277	5562
30......	1421	1848	2403	3125	4064	5284	6872
35......	1648	2143	2787	3625	4714	6129	7971
40......	1847	2402	3123	4061	5281	6868	8931
45......	2017	2624	3412	4437	5769	7502	9754
50......	2163	2812	3657	4756	6184	8041	10457
55......	2289	2976	3871	5034	6545	8512	11069
60......	2400	3121	4059	5277	6863	8925	11605
65......	2500	3252	4229	5500	7150	9298	12092
70......	2589	3367	4378	5692	7403	9627	12517
75......	2672	3475	4519	5875	7640	9936	12922
80......	2740	3564	4633	6026	7836	10190	13250
85......	2805	3648	4744	6169	8021	10430	13565
90......	2864	3725	4843	6298	8190	10649	13850
95......	2919	3796	4936	6418	8346	10855	14112
100.....	2966	3856	5014	6521	8480	11026	14340

[1] For density and composition indices other than 100 percent, multiply tabular values by factors given in table 11.

Table 11.--*Reduction factors to be used to obtain total yield per acre (cubic feet - inside bark) for density and composition indices other than 100 percent*[1]

Density index (percent)	Reductions factors, for composition index:								
	20 percent	30 percent	40 percent	50 percent	60 percent	70 percent	80 percent	90 percent	100 percent
20........	0.0626	0.0738	0.0869	0.1024	0.1205	0.1419	0.1672	0.1969	0.2319
30........	.0905	.1066	.1256	.1479	.1741	.2052	.2416	.2845	.3351
40........	.1176	.1385	.1631	.1921	.2262	.2664	.3137	.3695	.4352
50........	.1440	.1696	.1997	.2352	.2769	.3262	.3841	.4525	.5330
60........	.1699	.2001	.2357	.2775	.3269	.3850	.4534	.5340	.6289
70........	.1954	.2301	.2710	.3192	.3760	.4428	.5215	.6141	.7233
80........	.2206	.2599	.3060	.3604	.4244	.4998	.5887	.6934	.8166
90........	.2455	.2891	.3405	.4010	.4723	.5562	.6550	.7715	.9086
100.......	.2702	.3181	.3747	.4413	.5197	.6121	.7209	.8491	1.0000
110.......	.2946	.3469	.4086	.4812	.5667	.6675	.7861	.9260	1.0904
120.......	.3188	.3755	.4423	.5208	.6134	.7225	.8507	1.0020	1.1800
130.......	.3428	.4037	.4756	.5600	.6596	.7768	.9146	1.0774	1.2688
140.......	.3667	.4318	.5086	.5990	.7055	.8308	.9785	1.1523	1.3572

[1] Multiply values in table 10 by above factors.

Table 12.—*Loblolly pine yield in rough (unpeeled) units per acre, all trees 6.0 inches d.b.h. and larger included*

For composition index — 100 percent[1/]

DENSITY INDEX — 20 PERCENT

Age (years)	Yield per acre, for site index:						
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Units	Units	Units	Units	Units	Units	Units
20	0.6	1.1	1.9	3.4	5.0	6.6	8.8
25	1.6	2.6	3.9	5.5	7.4	9.6	12
30	2.6	3.8	5.3	7.1	9.6	12	14
35	3.2	4.5	6.2	8.0	10	14	17
40	3.5	5.0	6.8	8.8	11	14	18
45	3.8	5.4	7.3	9.6	12	15	18
50	4.1	5.6	7.8	10	13	16	19
55	4.3	5.9	8.2	10	14	17	20
60	4.5	6.2	8.5	11	14	17	20
65	4.7	6.4	8.8	11	14	18	21
70	4.9	6.6	9.1	11	14	18	21
75	5.0	6.8	9.4	12	14	18	22
80	5.1	7.0	9.6	12	15	18	22

DENSITY INDEX — 40 PERCENT

Age (years)	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
20	1.0	1.7	2.2	5.5	8.8	11	15
25	2.6	4.1	6.6	9.6	13	17	22
30	4.3	6.5	9.6	13	16	21	26
35	5.6	8.0	11	14	19	24	30
40	6.3	8.8	12	16	21	26	32
45	6.8	9.6	13	17	22	27	34
50	7.2	10	14	18	23	28	35
55	7.6	10	14	18	24	29	36
60	8.0	11	15	19	25	30	37
65	8.4	11	15	20	25	30	38
70	8.8	12	16	21	26	31	38
75	9.0	12	16	21	26	32	38
80	9.2	13	17	22	26	32	39

1/ For other units of measure or for different composition indices, apply red_ction factors given in table 13.

Table 12.--*Loblolly pine yield in rough (unpeeled) units per acre, all trees 6.0 inches d.b.h. and larger included--Continued*

For composition index -- 100 percent[1].

DENSITY INDEX -- 60 PERCENT

Age (years)	Yield per acre, for site index -- 50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Units	Units	Units	Units	Units	Units	Units
20............	1.2	2.1	3.5	6.9	12	16	21
25............	3.0	5.0	8.8	14	18	23	30
30............	5.7	8.8	13	18	23	30	37
35............	7.7	11	16	21	27	34	41
40............	8.8	13	18	23	30	36	44
45............	9.6	14	19	25	32	38	46
50............	10	14	20	26	33	40	49
55............	11	15	21	27	34	41	50
60............	12	16	22	29	35	42	51
65............	12	17	22	30	36	44	52
70............	13	17	23	30	37	45	53
75............	13	18	24	30	38	46	54
80............	14	18	25	31	38	46	55

DENSITY INDEX -- 80 PERCENT

Age (years)	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
20............	1.4	2.3	4.0	7.9	14	21	27
25............	3.4	5.8	10	17	23	30	38
30............	6.6	10	16	23	30	38	47
35............	9.6	14	20	27	35	43	53
40............	11	16	22	30	38	47	57
45............	13	18	24	33	42	50	60
50............	14	19	26	35	44	52	62
55............	14	20	27	36	45	54	64
60............	15	21	29	37	46	55	66
65............	16	22	30	38	47	57	67
70............	16	22	30	39	49	58	68
75............	17	23	31	40	50	59	69
80............	18	23	32	41	50	60	70

[1] For other units of measure or for different composition indices, apply reduction factors given in table 13.

Table 12.—*Loblolly pine yield in rough (unpeeled) units per acre, all trees 5.0 inches d.b.h. and larger included—Continued*

For composition index — 100 percent[1/].

DENSITY INDEX — 100 PERCENT

Age (years)	Yield per acre, for site index:						
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Units	Units	Units	Units	Units	Units	Units
20	1.4	2.4	4.2	8.0	16	26	33
25	3.6	5.8	10	19	28	38	47
30	7.0	12	18	27	37	47	58
35	11	17	23	33	42	54	64
40	13	20	27	37	47	58	70
45	15	22	30	39	50	62	74
50	17	23	32	42	53	65	76
55	18	25	34	44	55	67	78
60	18	26	35	46	57	70	80
65	19	27	36	47	58	71	82
70	20	28	37	48	60	73	83
75	21	29	38	49	61	74	85
80	21	30	39	50	62	75	86

DENSITY INDEX — 120 PERCENT

Age (years)	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
20	1.5	2.4	4.3	8.8	18	30	39
25	3.8	6.1	11	22	31	43	55
30	7.2	12	21	32	42	54	68
35	12	18	28	40	50	63	78
40	15	22	33	45	55	69	84
45	18	26	36	48	59	74	89
50	20	28	39	51	63	77	93
55	22	30	41	53	65	79	95
60	23	31	42	55	67	82	98
65	24	33	44	57	69	83	99
70	25	34	45	58	70	85	101
75	26	34	46	59	71	86	102
80	26	35	47	60	72	88	104

1/ For other units of measure or for different composition indices, apply reduction factors given in table 13.

Table 13.--*Reduction factors to be used to obtain yield in units and cords for stands of different composition indices*[1]

Composition index (percent)	Units (160 cubic feet) of rough wood	Units (160 cubic feet) of peeled wood	Cords (128 cubic feet) of rough wood	Cords (128 cubic feet) of peeled wood
20.............	0.300	0.251	0.375	0.314
30.............	.348	.292	.435	.365
40.............	.406	.340	.508	.425
50.............	.470	.394	.588	.493
60.............	.548	.459	.685	.574
70.............	.642	.538	.802	.673
80.............	.740	.620	.925	.776
90.............	.863	.723	1.079	.904
100............	1.000	.838	1.250	1.048

1/ Multiply values in table 12 by reduction factors given above.

Increment

Increment, the growth of loblolly pine in any stand over a period of time, is influenced by the same factors that affect yield--age, density and composition indices, and site quality. On the assumption that age is the only one of these factors to change with the lapse of time, estimates of increment can be made from the yield tables by merely subtracting the yield of a stand of given composition and density, growing on a site of known quality, from the yield of a similar stand at an older age. If, however, one or more of the variables other than age changes during the prediction period, the estimate of growth is likely to be in error. The possibilities of such changes are considered in the following paragraphs.

Site Changes

It is possible that the site index of any given area may change over a period of time. Scattered measurements and observations indicate that the site index of old fields may become lower with the passage of time, owing possibly to compacting and other soil changes. There is also the probability that in certain cases the site quality may improve because of improvement in soil texture and fertility caused by the inclusion of humus and litter. The amount of change in site index due to these or other causes can reasonably be expected to be quite small. Accordingly, until more adequate data are available, it is assumed that site quality remains the same during the life of a stand.

Composition Changes

In the mixed loblolly pine-hardwood forests, the hardwoods usually have a slower growth rate than the pine. Reasoning from this, it is probable that the proportion of hardwood basal area to total stand basal area will decrease with an advance in age of a given mixed stand. This change, however, is frequently compensated for by the increase in the number of stems of hardwoods present as the stand age increases. Since few specific data are available on these two compensating changes, the assumption is made, for growth prediction purposes, that no net changes occur in composition.

Density Changes

It has long been believed that the density of stocking of untreated forest tends to approach an equilibrium. In general, competition among trees is less severe in under-stocked stands than in normal stands, resulting in greater individual tree growth and a smaller loss due to mortality. The effect of more severe competition in over-stocked stands results in decreased individual tree growth and increased mortality. The net result is a gradual tendency for non-normal stands to come into equilibrium with their sites. The results of a recent study designed to determine the magnitude of density changes showed that the rate of change depended primarily upon the density of stocking and the age of the stand[8/]. Although other factors such as composition and site quality probably affect the rate of density change, there are at present no measures of their influence. Table 14 shows

8/ Chaiken, L. E. The approach of loblolly and Virginia pine stands toward normal stocking. Jour. For.

the average change in density index for 5-year periods, depending upon the initial density of stocking and age of the stand. To illustrate: a 25-year-old stand which is 60 percent stocked will increase 6.5 percent (read from table 14) in stocking during the next 5-year period; hence, in 5 years, the stand will be 30 years old and 66.5 percent stocked.

Table 14.--*Average change in density index (percent) for 5-year periods, by age of stand and density of stocking at beginning of period*[1]

Density index at beginning of period (percent)	Change in density index (percent), for stand age (years) of:												
	15	20	25	30	35	40	45	50	55	60	65	70	75
20..............	12.5	9.0	6.5	5.5	4.5	4.0	3.5	3.0	**2.5**	**2.0**	**1.5**	**1.0**	**0.5**
30..............	12.5	9.0	6.5	5.5	4.5	4.0	3.5	3.0	**2.5**	**2.0**	**1.5**	**1.0**	**0.5**
40..............	12.5	9.0	6.5	5.5	4.5	4.0	3.5	3.0	**2.5**	**2.0**	**1.5**	**1.0**	**0.5**
50..............	12.5	9.0	6.5	5.5	4.5	4.0	3.5	3.0	**2.5**	**2.0**	**1.5**	**1.0**	**0.5**
60..............	12.5	9.0	6.5	5.5	4.5	4.0	3.5	3.0	**2.5**	**2.0**	**1.5**	**1.0**	**0.5**
70..............	12.5	9.0	6.5	5.5	4.5	3.5	3.0	2.5	**2.0**	**1.5**	**1.5**	**1.0**	**0.5**
80..............	11.5	8.5	6.5	5.0	4.0	3.0	2.5	2.0	**1.5**	**1.0**	**1.0**	**1.0**	**0.5**
90..............	10.5	7.5	6.0	4.5	3.5	2.5	2.0	1.5	**1.0**	**0.5**	**0.5**	**0.5**	**0.5**
100.............	8.5	6.0	5.0	3.5	2.5	2.0	1.0	0.5	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
110.............	6.5	5.0	3.5	2.5	1.5	1.0	0.0	-0.5	...	...	...	...	...
120.............	4.0	3.0	2.0	1.5	0.5	0.0	-1.0	-1.5	...	...	...	...	...
130.............	2.0	1.5	1.0	0.0	-0.5	-1.0	-2.0	-2.5	...	...	...	...	...

[1] To obtain density index 5 years hence, add density change to density index at the beginning of the period. Underlined values represent extrapolations.

Estimation of Future Yields and Growth

The procedure involved for estimating the future yield of a present stand may be shown by the following illustration. Reference to table 12 shows that a stand 30 years of age, site index 70 feet, density index 40 percent, and composition index 100 percent, yields 9.6 units of rough wood per acre. In 5 years the stand will be 35 years of age, and although the site and composition indices will remain unchanged, the density index will be 45.5 percent, an increase of 5.5 percent, from table 14. Again referring to table 12, it is calculated that the stand will then yield 12.6 units of rough wood per acre (interpolation between the various sections of table 12 is necessary to obtain yields for intermediate densities). The increment, therefore, for the 5-year period will be 3.0 units (12.6 units - 9.6 units), or an average increment of 0.6 units of rough wood per acre per year. The latter figure is termed "periodic annual increment" and indicates the allowable annual cut if drain is to equal growth. Table 15 gives periodic annual increments, corrected for density change, in units of rough wood per acre for stands of different ages, site quality, and density of stocking. If it is desired to obtain increment for stands other than 100 percent composition or in terms of other measures of volume, apply reduction factors given in table 13.

Table 15.--*Periodic annual increment in rough (unpeeled) units per acre, corrected for density changes. All trees 6.0 in inches d.b.h. and larger included*

For composition index -- 100 percent.

Age of stand at beginning of period. (years)	Periodic annual increment, for site index: 50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Units	Units	Units	Units	Units	Units	Units
DENSITY INDEX - 20 PERCENT							
20..........	.27	.43	.65	.80	.99	1.23	1.57
25..........	.31	.42	.53	.66	.85	1.06	1.26
30..........	.25	.34	.44	.60	.74	.91	1.08
35..........	.20	.27	.38	.47	.59	.70	.89
40..........	.18	.25	.34	.44	.55	.63	.75
45..........	.16	.22	.30	.39	.49	.58	.69
50..........	.14	.19	.26	.34	.41	.48	.54
55..........	.13	.18	.23	.30	.35	.40	.45
60..........	.10	.15	.19	.24	.30	.33	.35
65..........	.08	.13	.16	.20	.25	.27	.30
70..........	.06	.10	.13	.16	.20	.22	.25
75..........	.04	.07	.10	.12	.14	.17	.19
DENSITY INDEX - 40 PERCENT							
20..........	.35	.57	.91	1.17	1.37	1.65	2.06
25..........	.45	.62	.77	.92	1.10	1.38	1.62
30..........	.37	.46	.60	.79	.95	1.10	1.30
35..........	.26	.35	.49	.64	.74	.86	1.07
40..........	.22	.31	.42	.57	.67	.73	.83
45..........	.21	.27	.38	.49	.57	.66	.74
50..........	.18	.24	.32	.38	.46	.52	.58
55..........	.17	.22	.28	.33	.40	.45	.50
60..........	.14	.18	.23	.29	.32	.38	.43
65..........	.12	.14	.20	.23	.27	.32	.37
70..........	.10	.12	.16	.20	.22	.27	.32
75..........	.07	.10	.14	.16	.18	.22	.26

Table 15.--*Periodic annual increment in rough (unpeeled) units per acre, corrected for density changes. All trees 6.0 inches d.b.h. and larger included--Continued.*

For composition index — 100 percent.

DENSITY INDEX -- 60 PERCENT

Age of stand at beginning of period (years)	Periodic annual increment, for site index:						
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Units	Units	Units	Units	Units	Units	Units
20	.40	.66	1.14	1.59	1.79	2.03	2.53
25	.58	.86	1.06	1.22	1.32	1.72	1.98
30	.51	.63	.79	.94	1.12	1.35	1.54
35	.36	.45	.58	.75	.89	1.02	1.17
40	.28	.39	.53	.66	.77	.86	.96
45	.24	.33	.45	.54	.64	.73	.85
50	.21	.28	.34	.41	.49	.55	.66
55	.18	.23	.30	.34	.43	.47	.52
60	.16	.21	.26	.30	.34	.39	.45
65	.14	.18	.22	.26	.31	.34	.40
70	.12	.15	.18	.23	.27	.30	.34
75	.09	.13	.16	.20	.23	.25	.29

DENSITY INDEX — 80 PERCENT

Age of stand at beginning of period (years)	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
20	.43	.70	1.26	1.98	2.19	2.50	3.01
25	.66	1.04	1.38	1.54	1.66	2.04	2.38
30	.66	.82	.94	1.09	1.34	1.56	1.74
35	.48	.57	.69	.88	1.04	1.22	1.31
40	.32	.45	.57	.71	.82	.94	1.02
45	.26	.35	.47	.57	.67	.78	.85
50	.22	.30	.36	.42	.51	.56	.58
55	.19	.25	.31	.35	.43	.47	.51
60	.17	.22	.27	.30	.35	.39	.43
65	.15	.19	.24	.28	.33	.35	.38
70	.14	.18	.22	.26	.30	.31	.33
75	.11	.16	.19	.23	.26	.29	.30

Table 15.--*Periodic annual increment in rough (unpeeled) units per acre, corrected for density changes. All trees 6.0 inches d.b.h. and larger included--Continued*

For composition index -- 100 percent.

DENSITY INDEX -- 100 PERCENT

Age of stand at beginning of period (years)	Periodic annual increment, for site index:						
	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
	Units	Units	Units	Units	Units	Units	Units
20..........	.45	.71	1.30	2.34	2.55	2.83	3.30
25..........	.68	1.20	1.67	1.83	2.00	2.28	2.61
30..........	.82	1.04	1.16	1.31	1.48	1.66	1.82
35..........	.61	.70	.82	.97	1.10	1.25	1.42
40..........	.41	.51	.66	.78	.84	.95	1.02
45..........	.28	.37	.50	.61	.69	.82	.79
50..........	.23	.30	.37	.42	.53	.56	.50
55..........	.19	.24	.31	.34	.43	.45	.46
60..........	.17	.22	.26	.29	.34	.36	.38
65..........	.15	.19	.23	.26	.29	.32	.35
70..........	.14	.17	.21	.23	.26	.28	.30
75..........	.11	.15	.18	.20	.22	.26	.28

DENSITY INDEX -- 120 PERCENT

Age of stand at beginning of period (years)	50 feet	60 feet	70 feet	80 feet	90 feet	100 feet	110 feet
20..........	.46	.72	1.38	2.54	2.81	3.04	3.55
25..........	.68	1.26	2.00	2.21	2.34	2.49	2.70
30..........	.92	1.26	1.48	1.56	1.68	1.77	1.92
35..........	.74	.86	.92	1.00	1.09	1.22	1.39
40..........	.54	.62	.73	.78	.83	.88	.94
45..........	.31	.39	.46	.55	.60	.65	.69
50..........	.22	.28	.30	.33	.35	.38	.40
55..........							
60..........							
65..........							
70..........							
75..........							

Pulpwood Rotations

The age at which a stand should be cut, that is, the rotation age, depends upon a number of factors. Among these are: culmination of mean annual increment, the type and quality of product desired, the costs of harvesting, and the financial and silvicultural aspects of forest management. It is generally considered that in so far as maximum volume production is concerned, the length of the rotation period should be governed by the age at which mean annual increment culminates. It is indicated in figure 8 that the culmination of mean annual increment depends upon the site quality and density index. Thus figure 8 (A) shows that for density index 100 percent, increment culminates at a younger age for stands of good site quality than for stands of poorer site quality, ranging from 28 to 45 years of age. Figure 8 (B) shows that for stands of site index 80 feet, culmination occurs at 28 years for 20 percent stocked stands and at 37 years for 120 percent stocking[9]. Although the culmination of mean annual increment may occur earlier in the life of stands which are of good site quality but poorly stocked, it should be noted that greater annual production is obtained in fully stocked stands.

9/ These values were computed from table 12 by dividing the yield at each age by the age in years, thus giving the increment per year; that is, everage for the previous life of the stand. Mean annual increment may be similarly computed for stands of other conditions.

In the foregoing discussion, no recognition is made of any changes in density due to approach of understocked stands toward normal stocking. Although it is not the purpose of this publication to discuss methods of forest management, it is intended to provoke thought as to the management of non-normal stands by briefly considering the effect of density change upon the culmination of mean annual increment. The curves in figure 8 assume that the density index of stands will not change with the passing of time. These curves therefore cannot be used to forecast the age at which stands of site index 80 will culminate in mean annual increment. They merely show for the given site, those combinations of age and density which result in culmination. Because it is known that both overstocked and understocked stands do tend to approach "normal" or full stocking this trend must be accounted for in forecasting culmination.

In figure 9, where the influence of density change is accounted for, the mean annual increment over the life of 6 stands, each starting at 20 years of age with different densities of stocking, is shown. It is evident that figure 9 presents a somewhat different relationship than that indicated by figure 8. When density changes are recognized mean annual increment culminates earlier in fully stocked stands than in those of lesser stocking, a relationship quite the opposite of that found when density changes are ignored. As expected, maximum annual production and early culmination is attained in heavily stocked stands growing on sites of good quality.

Limited space makes it impossible to present here the multitude of tables or charts similar to figure 9 which would be necessary to

allow the reader to forecast the culmination age of any given stand. However, the procedure outlined as follows is simple and may be used for individual cases.

Using as an example the lowest curve in figure 9; that is, a stand 20 percent stocked at 20 years of age, site index 80 feet and composition index 100 percent, the computations are:

Age (years)	Density index (percent)	Yield (units)	Mean annual increment (units)
20	20.0	3.4	0.170
25	29.0	7.4	.296
30	35.5	11.3	.377
35	41.0	15.0	.428
40	45.5	18.1	.452
45	49.5	21.0	.466
50	53.0	23.7	.474
55	56.0	25.9	.471
60	58.5	27.8	.463
65	60.5	29.6	.455
70	62.0	31.0	.443

Starting with age 20 years and density index 20 percent, the changes in density are read from table 14, accumulating the changes for each successive 5-year period. The yield for each age period is interpolated from table 12. The yield divided by the age gives the mean annual increment; in this example the maximum increment or culmination is reached when the stand is 50 years of age.

Whether or not the rotation or culmination age is a matter for practical consideration by the pulpwood grower depends largely

upon the intentions of management. However, in an era of large industrial ownership and in a region where many smaller holdings are kept in a single family for several generations, a forward look of 50 years may not be entirely visionary. Consider for this period of time the possible advantages of cutting a given stand at the culmination of its mean annual increment, as compared to cutting the same stand as soon as growth has produced an operable cut. Assume that when a given tract is acquired it bears a 20-year-old stand 60 percent stocked with a site index of 80. At the time of acquisition then this stand will show a mean annual increment of 0.34 units, figure 9, and will have a standing value of 6.8 units per acre (20 x 0.34). Two years after acquisition at the age of 22 years the stand will show a mean annual increment of 0.48 units and have a standing volume of 10.56 units (22 x 0.48 units). Therefore if approximately 10 units can be produced every 22 years, 3 cuts of this amount can be taken from the land at 2, 24, and 46 years after acquisition. The total production per acre over a 50-year period therefore will be 3 x 10.56 or 31.68 units.

If however, the same stand was not cut until the culmination of mean annual increment at 40 years (figure 9) of age, or 20 years after acquisition, the yield at that time would be (40 x 0.79 units) or 31.60 units. The remaining 30 of the 50-year period would then produce an additional 21.60 units (30 x 0.72 units). Therefore by cutting at the culmination of mean annual increment the total production of wood for the 50 years would be 31.60 + 21.60 or 53.20 units as compared to 31.68 units where the same stand was cut each time a volume of 10 units was produced. The above example is based, of course, upon the assumption that application of forest

practice rules will produce a stand of approximately the same stocking promptly after each cut.

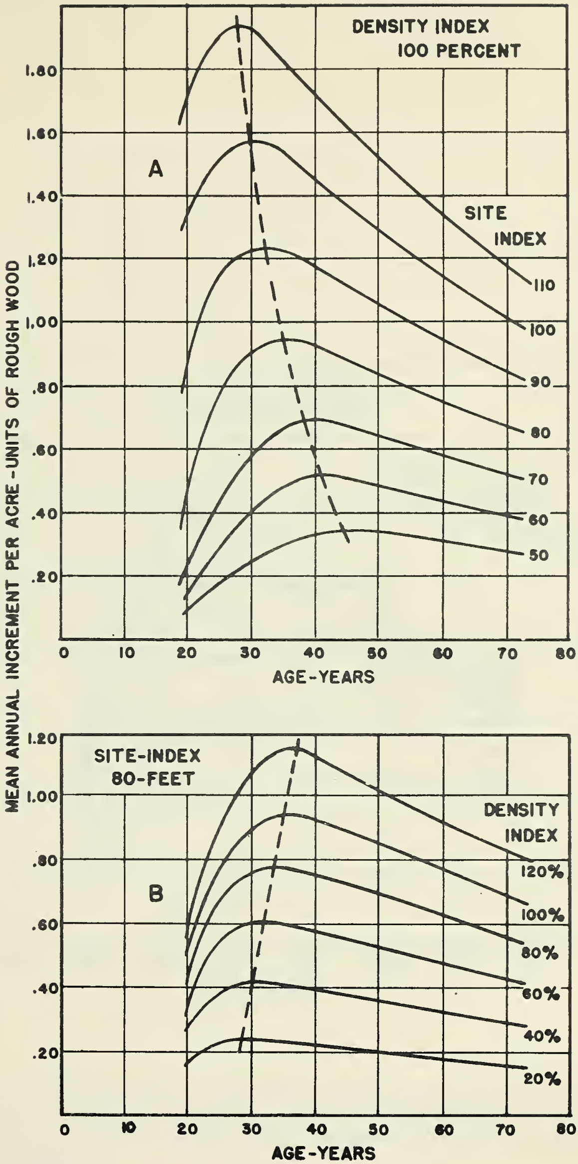

Figure 8.—Mean annual increment per acre in units of rough wood, for trees 6.0 inches in diameter and larger. (A) Density index 100 percent for stands of different site quality. (B) Site index 80 feet for stands of different densities. Broken line intersects culminations of increment.

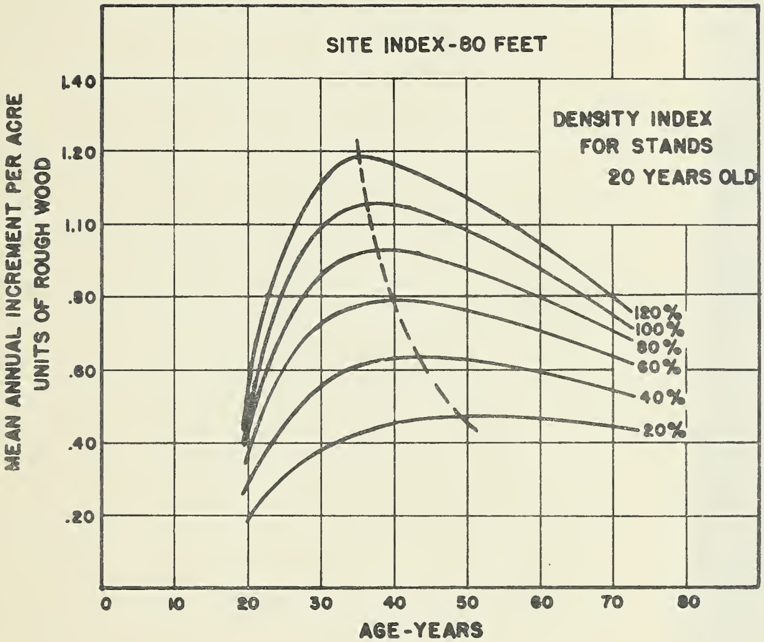

Figure 9.--Mean annual increment per acre corrected for density changes. For stands of different densities at 20 years of age. Broken line intersects culminations of increment.